THE DOUGLAS-FIR BEETLE--ITS SEASONAL HISTORY, BIOLOGY, HABITS, AND CONTROL

Respectfully submitted,

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PREFACE

The Douglas-fir beetle (Dendroctonus pseudotsugae Hopk.) has grown increasingly injurious, during the past few years, to the Douglas fir in the northwestern United States. This damage has been so great in some areas that steps have been taken to control the bark beetle in the Glacier National Park in 1930 and the Shoshone National Forest in 1931 and 1932. The institution of these control projects showed a need for better knowledge of the biology and habits of the beetle, which would serve as a basis for improving control methods. A study was begun, therefore, to secure the required data.

The investigation, at first, attempted to ascertain only the seasonal history and habits of the insect, but this later was extended to include experimental controls and a study of the parasites and predators which attack the Douglas-fir beetle. Work was begun on the Kaniksu National Forest, near Metaline Falls, Wash., early in 1930, and was continued through the 1931 and 1932 seasons. The first report[1] of the project contained only biological notes concerning the Douglas-fir beetle, a description of the experiments then in an incomplete condition, and an annotated list of the important parasites and predators. Of necessity therefore, some of the data in this report are supplementary to, and in substantiation of the first report and, consequently, much of the data in the preceding report have been incorporated into this one.

The writer was assisted by Messrs. Francis B. Foley, David O. Scott, and Lowell Farmer at various times during the 1931 investigations, and by Francis B. Foley throughout the 1932 season.

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1 Bedard, W. D. 1932. Douglas-Fir Beetle Investigations 1931. (Unpublished report).

PARENT ADULT EMERGENCE AND REATTACK

Investigators of the mountain-pine beetle have been recording for some time the presence of emergence holes in trees that have been too recently attacked to produce mature brood, and it was noted also that the holes led from egg galleries. A similar condition was found to obtain in Douglas fir, and suggested the possibility of parent adult emergence with subsequent attacks in a second Douglas fir. It was obvious that if these parent adult beetles did emerge after propagating one brood and attacked other trees to generate a second brood, the number of infested trees the following year would be approximately twice the number normally to be expected and thus, in some measure, explain undue increases of this insect.

In the study of this problem, cages were constructed of wire-screen around the basal ten feet of green Douglas-fir trees and infested material placed in the cages in order to connect one group of emerging parent adults definitely with a subsequent attack. The cage found most suitable and most easily constructed was a simple tepee made of poles and wire screen. The screen was securely sealed by tacking the top edge to the tree and the overlapping sides to the poles. The base was spread sufficiently to allow room for the insertion of infested logs and the bottom edge of the screen was then buried in the ground, in order to prevent the escape of beetles.

Three such cages were constructed, one in 1931 and one in 1932 containing infested material from May-attacked trees, and one in 1931 containing infested material from July-attacked trees. In all cases, the parent beetles emerged and attacked the green tree. Concurrent with and possibly due to the attraction exerted by the attacks within the cages, the trees were attacked above the enclosure by additional beetles. It was

noted also that parent adults were emerging from the trees from which the infested material had been cut, thus showing that emergence within the cages was not abnormal.

When it was certain that no more parent adults would emerge from the inserted material, the cages were transferred to green trees. The trees which had received the second attack were then felled and the portions that had been caged were transferred to the cages on the green trees in order to ascertain if the parent adults would emerge and make a third attack. Third attacks were not made in any case.

All the material, both the original infested logs and the trees containing second attacks, was thoroughly examined at the conclusion of each experiment and it was found that although many of the parent adults had emerged from their first attack, some of the remaining parent adults were dead. It is known, however, that parent adults and new adults are attacking at the same time and, consequently, attack trees together. Most of these dead beetles, therefore, are probably parent adults which had made their second attack. Table I summarizes these findings.

TABLE I

ANALYSIS OF LOGS IN PARENT ADULT EMERGENCE CAGES

Cage	Attack	No. of attacks	% of parent adult emergence	No. of dead parent adults	No. of living parent adults
1	First attack - May 16, 1931	338	52.3	32	75
	Second attack - July 8, 1931	177	0	179	0
2	First attack - July 15, 1931	284	53.5	71	1
	Second attack - May 18, 1932	152	0	12	186
3	First attack - May 6, 1932	79	30.3	17	25
	Second attack - July 5, 1932	24	0	5	30

It will be noted in Table I, cage 2, that the beetles which attacked in July, wintered over and did not make their second attack until May of the following year.

In connection with the above study it was discovered that parent adults were emerging from a windfall which was being observed for the oviposition of parasites. As the beetles emerged from the windfall, they would remain a short time on the bark stretching their wings, and finally fly away. After watching their activities for some time, it was suddenly realized that all beetles were taking flight toward the east. An investigation in this direction revealed a newly attacked tree about 50 feet from the windfall in which attacks were in progress. Beetles were then collected and liberated on the east, north and south sides of the newly attacked tree about 50 feet away from it. With only one exception, the beetles flew in the direction of the newly attacked tree. One beetle liberated north of the tree, circled rapidly twice and then flew in a southwest direction.

From these studies it can be stated that Douglas-fir beetle adults emerge from the trees after making one attack and enter other trees to make a second attack. This beetle, therefore, produces two broods in Douglas fir.

PROPORTION OF SEXES

In New Attacks

A study of the mountain-pine beetle revealed that there were more female than male beetles in newly attacked white pine trees and it was thought advisable to make a similar investigation in Douglas fir. This investigation showed that the Douglas-fir beetle females also predominate in numbers in the newly attacked trees. It can readily be seen that if

this were due to a numerical inequality of sexes in emerging broods, the infestation would increase beyond normal expectations in direct proportion to the number of extra females and, consequently, the problem would be an important one. Therefore, a study of the proportion of sexes in newly attacked trees was made in 1931 and it was found in an examination of 1493 galleries, containing a total of 2395 beetles, that there were 8 females for every 5 males. It also was learned in this study that height on the bole of the tree, exposure, or date after the tree had been attacked did not effect this ratio.

In the 1932 studies, 1000 galleries containing 1672 beetles were examined in newly attacked trees and it was found that there were 3 females to every 2 males. These examinations were distributed over the two attack periods as shown in the following table:

TABLE II
SEX OF DOUGLAS-FIR BEETLES FOUND IN NEWLY ATTACKED TREES
1932 SEASON

Attack period	No. of galleries	No. of females	No. of males	Sex ratio
May	500	500	332	3:2
July	500	500	340	3:2
Total	1000	1000	672	3:2

It is apparent in Table II that the period of attack does not influence the sex ratio. During the two field seasons, 2493 galleries in newly attacked Douglas-fir trees were examined. These contained a total of 4067 Douglas-fir beetles comprising 1574 males and 2493 females. Therefore, the sex ratio of Douglas-fir beetles in newly attacked Douglas-fir

trees is 6 females to 5 males.

In Emerging Broods

The importance of this numerical sex inequality obviously depends on whether or not it originates in the emerging broods. To answer this question, the genetalia of 1015 new adult beetles about to emerge were dissected and examined with the aid of a microscope. It was found that 501 were males and 514 females, or a sex ratio of one male to one female.

A similar study was performed in 1932, in which 500 new adults were collected from trees in each of the two emergence periods and were examined by the same method used in 1931. Table III shows the results from this study.

TABLE III
SEX OF DOUGLAS-FIR BEETLES EMERGING FROM BROOD TREES
1932 STUDY

Emergence period	No. of males	No. of females	Per cent males	Per cent females	Sex ratio
May	254	246	50.8	49.2	1:1
July	248	252	49.6	50.4	1:1
Total	502	498	50.2	49.8	1:1

Combining the data from the two field seasons, 2015 beetles were examined, 1003 of which were males and 1012 females, making a sex ratio of 1:1. There is, therefore, an equal number of males and females when the young adults emerge from the trees. Consequently, an unequal sex ratio is not a factor which causes an increase of D. pseudotsugae beyond that normally expected.

Cause of the Inequality in New Attacks

It has been shown that there is a greater number of females than males in newly attacked trees, in spite of the fact that males and females emerge from brood trees in equal numbers. It was thought that parent adult beetles which attack trees together with new adults might in some measure account for this sex inequality. Consequently, an experiment was performed to ascertain the sex of emerging parent adults prior to their second attack. Twenty-four square feet of newly attacked Douglas-fir material were placed in a large galvanized can. This can was especially constructed with a bottom sloping downward from the sides towards a hole in the center, so that all emerging insects eventually would fall into a glass container fastened to the bottom of the can. The container was emptied each day, and the sex of each Douglas-fir beetle was determined by dissection of the genetalia. When emergence was complete, it was found that 44 males and 111 females had emerged, making a sex ratio of 1:2.5 or 2:5, which is slightly more than 2 females for every male.

In another experiment on May 17, 1932, 10 overwintering parent adults which were alone in galleries were collected from material from which the parent adults later emerged and attacked another tree. These 10 beetles were liberated individually in cages and provided with fresh Douglas-fir material, in order to ascertain whether or not these parent adults require another fertilization before their second attacks. All made attacks, laid eggs and the eggs hatched into larvae.

Thus, parent adult beetles emerge in a ratio of 5 females to every 2 males, and mingle with new adults in attacking green trees. Also, these females are capable of laying fertile eggs without another fertilization. These two conditions undoubtedly cause the 5:8 sex ratio found in newly

attacked trees.

There were in addition, two other theories to be tested: first, that because male beetles follow females into the galleries, the males are exposed for a somewhat longer time and consequently more readily fall prey to predators; the second is a corollary of the first, in that the male beetles which leave one gallery in search of a second mate are subject to a number of dangers, most important of which are the predators.

To test these theories, a green Douglas-fir log was placed in a cage on May 15, 1932, and 5 male and 5 female Douglas-fir beetles were liberated in the cage. Male and female bark beetles were distinguished by collecting them from new galleries in which two beetles were working. On May 16, a male and female Enoclerus sphegeus (Fab.) were liberated in the cage and on each day following the liberation, an equal number of male and female bark beetles were placed in the cage. A total of 39 male and 39 female beetles were so liberated. An examination of the log one month later showed 23 attacks containing 23 females and 19 males. Thus, 20 males and 16 females had been eaten, showing that predators do destroy a slightly greater number of males.

PARTHENOGENSIS AND MATING HABITS

During the 1931 season, experiments were conducted to test the possibility of D. pseudotsugae possessing parthenogenetic ability. It was shown that the females of this insect can not produce fertile eggs without the aid of a male. Additional experiments on mating habits showed that fertilization takes place in the newly constructed gallery after it has progressed in the cambium from one-half to one inch, and that one male sometimes fertilizes more than one female.

ADDITIONAL NOTES ON BIOLOGY AND HABITS

The Douglas-fir beetle was described by Dr. Hopkins[2] in 1909. It attacks Douglas fir, western larch, and has been recorded from bigcone spruce, although Douglas fir is the preferred host. Attacks are indicated by red boring dust at the gallery entrances and lodged in the bark crevices and bark scales along the trunk of the tree. The foliage of the infested trees usually fades and turns red by late September of the season of attack, the needles dropping during the winter. However, this is not a sound criterion for the recognition of infested trees, because the leaves of many persist in a faded or green state until the following spring, when the transition is rapid through red to the needleless stage.

The beetles emerge from the old host and fly to a new one. Upon arrival at the new host, the female excavates the horizontal entrance tunnel through the bark to the cambium where she begins to tunnel the simple longitudinal egg gallery (Plate I fig. 1) up the tree in the inner bark, grooving the wood slightly. The male beetle crawls over the bark surface searching for a mate and when a female is discovered excavating an entrance hole, he will stand by and follow her into the tunnel as she progresses.

The egg galleries range from 3 to 23 inches in length with an average of 9.1 inches. Eggs are deposited in alternate groups (Plate I fig. 2) along the sides of the gallery, the egg groups containing from 2 to 13 eggs. The eggs are packed with frass to hold them in their niches and protect them from predators. Each female will deposit approximately 32 eggs which are distributed in the gallery as shown in Table IV.

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[2] Hopkins, A. D. 1909. The Genus Dendroctonus. U. S. D. A. Bull 83. pp. 106-107.

TABLE IV
AVERAGE DISTRIBUTION OF EGGS*

Inches	1	2	3	4	5	6	7	8	9	10	11-20
No. of eggs	1	4	6	5	4	3	2	2	2	2	0

*From examination of 376 galleries.

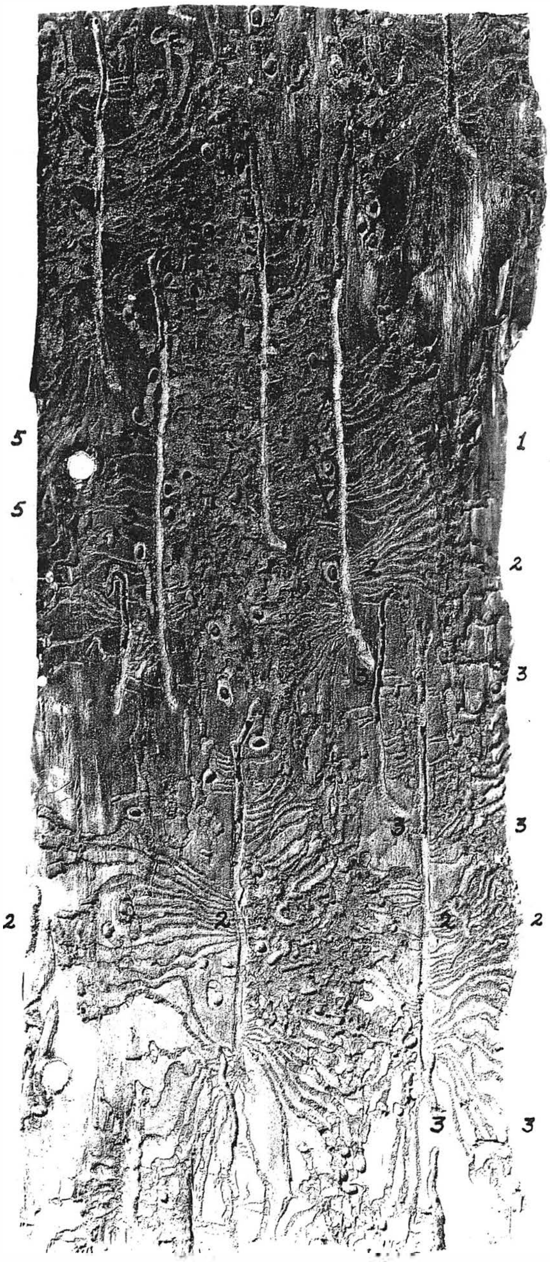
The eggs (Plate II fig. 2) are pearly-white in color, oval in shape, average 1.19 mm. in length, .672 mm. in width, and require an average of 15 days for incubation. The larvae (Plate II fig. 1) upon hatching, begin to feed and construct feeding tunnels at right angles to the egg gallery (Plate I fig. 2).

Owing to the fact that these larvae mine in the phloem of the tree, extreme difficulty arises in making daily observations for the purpose of recording details of larval development such as the number of molts and the time which elapses between the consecutive ecdyses. Several rearing devices were tested to accomplish this purpose, but, with one exception, they were not successful. Fair results were obtained by allowing adult female beetles to construct galleries in a thin sheet of inner bark, held between two plates of ordinary window glass. The bark was pared to such thinness that the beetles were allowed just sufficient room to work between the two glass plates, yet were kept visible at all times. It was found necessary to pack cotton around the bark between the two plates and to moisten the cotton daily in order to prevent excessive drying of the bark. The entire device was then wrapped in a black cloth to exclude light and thus make conditions more natural for the insect. Successful incubation of eggs was obtained in this apparatus, and the resultant larvae could be observed daily in the

PLATE I

Portion of Infested Douglas-Fir Bark

1. Complete egg gallery.
2. Larval mines showing also their origination from egg groups.
3. Attack.
4. Parent adult emergence hole
5. Pupal cell.


4
5
1
5
2
3
3
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2
2
2
3
3

larval tunnels until, during the second stadium, they passed out of sight into the host material. By transferring the larvae to a thinner piece of material it was hoped to prevent this disappearance, but the needed reduction in thickness caused rapid drying of the bark with subsequent larval mortality. Unfortunately, there is no anatomical character whereby the various instars can be distinguished from one another and, as the size of the body is so variable, the head-capsule dimensions are the only criteria for identification. It was possible, however, by this type of rearing, to secure head capsules from two successive ecdyses, namely, those of the first and second instars. With measurements made of these, and the aid of Dyar's Law[3], which is applicable also to these beetles, a series of figures can be calculated which represent the head capsule dimensions for any number of ecdyses which may follow the two already known. In order to terminate this series properly, head capsules from last larval instars were collected from pupal cells and measured to determine which of the calculated figures is that of the last instar.

Fifty head capsules each of the first, second and last instars were secured and measured. In addition to the usual measurements of length and width, a third measurement, the width of the frons (Plate III), was taken. This additional dimension was used because the head capsules of parasitised larvae are often broken in which case the frons is always intact, and it was hoped to use this study in relation to certain parasites. Table V gives a comparison of the head-capsule dimensions as obtained by the above method, with the average dimensions secured by the actual measurement of 200 entire head capsules from each instar.

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[3] Dyar, H. G. 1890. The Number of Molts of Lepidopterous Larvae. Psyche 5: 420-422.

PLATE II

Dendroctonus pseudotsugae (Hopk.)

1. Larva x 10. Lateral view.

2. Egg x 10.

3. Pupa x 10. Ventral view

4. Imago x 10. Dorsal view

5. Front of adult head x 10, showing epistomal process with parallel sides.

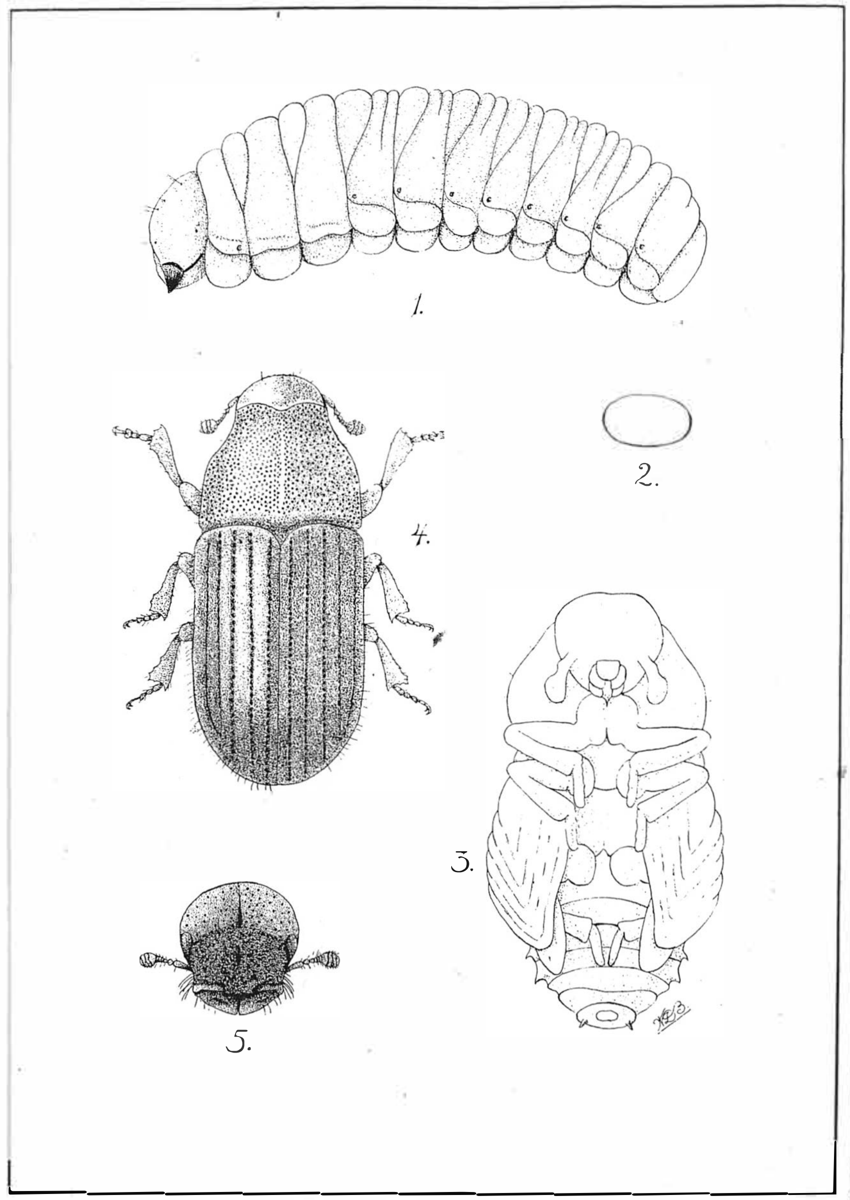
1.
2.
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TABLE V

COMPARISON OF THEORETICAL AND ACTUAL DIMENSIONS OF HEAD CAPSULES OF DOUGLAS-FIR BEETLE LARVAE

Dimension	Instar	Theoretical measurements	Actual measurements: Mean	Standard deviation	Minimum	Maximum	Individuals measured
		Mm.	Mm.	Mm.	Mm.	Mm.	Number
Length	1	[a] 0.454	0.462	0.031	0.428	0.523	200
	2	[a] .583	.552	.0197	.500	.600	200
	3	.746	.734	.0327	.650	.800	200
	4	.955	.919	.0547	.785	1.025	200
	5	[a] 1.21	1.24	.0788	1.125	1.375	200
Width	1	[a] .507	.523	.024	.476	.585	200
	2	[a] .644	.615	.0126	.585	.685	200
	3	.824	.791	.0478	.700	.850	200
	4	1.05	1.03	.0803	.900	1.20	200
	5	[a] 1.34	1.38	.0766	1.238	1.50	200
Width of frons	1	[a] .270	.278	.0475	.230	.385	200
	2	[a] .347	.365	.0217	.350	.400	200
	3	.444	.482	.030	.400	.550	200
	4	.568	.618	.0479	.500	.700	200
	5	[a] .727	.811	.0455	.666	.900	200

[a] Mean of actual measurements of 50 head capsules.

This table shows that the theoretical dimensions for the first, second and last instars check very closely with those obtained by the actual measurement of a large number of additional head capsules and that the material is well centered within the range. Because these dimensions check so closely and because all head capsules not of the first, second and fifth

PLATE III

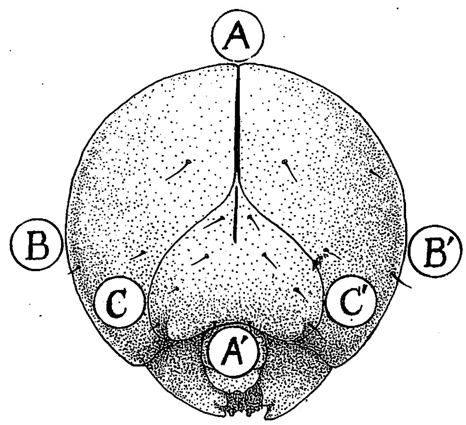
Head Capsule of D. *pseudotsugae* Larva Showing Measurements

Taken in the Study of Larval Development.

A-A' - Length

B-B' - Width

C-C' - Width of frons.


A
B
B′
C
C′
A′

instars fell definitely into two groups, the writer felt justified in calling these the third and fourth instars and checking them against the theoretical dimensions.

It will be noted that there is some overlapping between the sizes of the head capsules of the various instars. However, when a doubtful case occurs with one measurement, it has been found that one or both of the other two measurements will show to what instar the head capsule belongs.

Having thus established the number of instars of the host larva, it was desired to determine the approximate duration of each stadium. Taylor[4] describes a method for so doing when the larvae to be studied are hidden in the host material. Briefly, this is done by collecting a number of larvae each day and recording the instars collected under the date of collection. Then the length of each stadium can be calculated by counting the number of days from the first appearance of one instar to the first appearance of the next instar and the number of days between the last dates of appearance of the same two instars, adding these two numbers together, and dividing their sum by two.

In the application of this method, approximately 50 Douglas-fir beetle larvae were collected daily from a regular route which comprised 10 trees, 2 of which were windfalls. These trees represented varying conditions of bark thickness and exposure to the sun, and at each collection larvae were taken from all four sides of the tree. This diversified material was selected because of the effect which temperature and humidity exert on the development of bark-beetle larvae. Table VI shows the incidence of the

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[4] Taylor, R. L. 1930. A Simple Statistical Method of Determining the Approximate Duration of the Instars of Leaf-Mining Larvae and Others. Jour. of Econ. Ent. 23: 587-595.

various instars as found by these collections and the application of Taylor's method for the determination of the lengths of the various stadia.

TABLE VI
RANGE OF OCCURRENCE OF THE VARIOUS INSTARS OF THE
DOUGLAS-FIR BEETLE AND THE CALCULATED LENGTH OF THE STADIA

Instar	First occurrence	Interval till first occurrence of next stadium	Last occurrence	Interval till last finding of next stadium	Average duration of stadium
		Days		Days	Days
Instar 1	June 9	6	July 15	6	6
Instar 2	June 15	15	July 21	11	13
Instar 3	June 30	14	Aug. 1	18	16
Instar 4	July 14	13	Aug. 19	19	16
Instar 5	July 27	18	Sept. 7	16	17
Pupa	Aug. 14	-	Sept. 23	-	-

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Thus, the approximate durations of the various stadia, from the first instar to the fifth, are 6, 13, 16, 16 and 17 days, respectively.

During this period of development, approximately 40 per cent of the larvae migrate from between the bark and wood into the inner bark where they are hidden from view when the bark is removed from the tree. When the larvae have reached the fifth and last instar, they excavate a shallow pupal cell (Plate I fig. 5) in which they transform to pupae (Plate II fig. 3). These may be either exposed or hidden when the bark is removed, dependent on whether or not the larva had gone into the bark. The pupal stage requires an average of eight days for completion, that is, from larva to new adult.

The new adults feed after transformation for a considerable time

before emerging. Those reaching the new adult stage in late August and September feed until the end of the current season, overwinter, resume feeding in the spring of the following year and emerge in May. Those transforming in June, feed until they are ready for emergence in July of the same year. These beetles emerge by boring directly out through the bark.

SEASONAL HISTORY

In the early spring before insect activity begins, two distinct overwintering brood stages of the Douglas-fir beetle are to be found in localities approximating the conditions in the vicinity of Metaline Falls, Washington. A survey of 461 infested trees in the Sullivan Creek drainage of the Kaniksu National Forest showed that 62.4 per cent of the trees contained new adult beetles and 37.6 per cent contained mature larvae and overwintering parent adult beetles.

quote

The first attacks begin early in May and continue not longer than the first week in June. These are made by the combined efforts of the overwintering parent adults from the second group of trees and the overwintering new adults from the first group. The brood resulting from these early attacks develops normally (Plate IV) and is in the new adult stage by the latter part of August. These beetles continue to feed in the trees throughout the warm days of fall, overwinter, emerge and attack during May and the first week in June of the following year. This is the brood found as new adults in the spring.

The second attack period begins shortly before the middle of July and continues almost to the middle of August. The attacks in this period are made by new adults which matured from the larvae in the second group

PLATE IV

SEASONAL HISTORY CHART

Legend

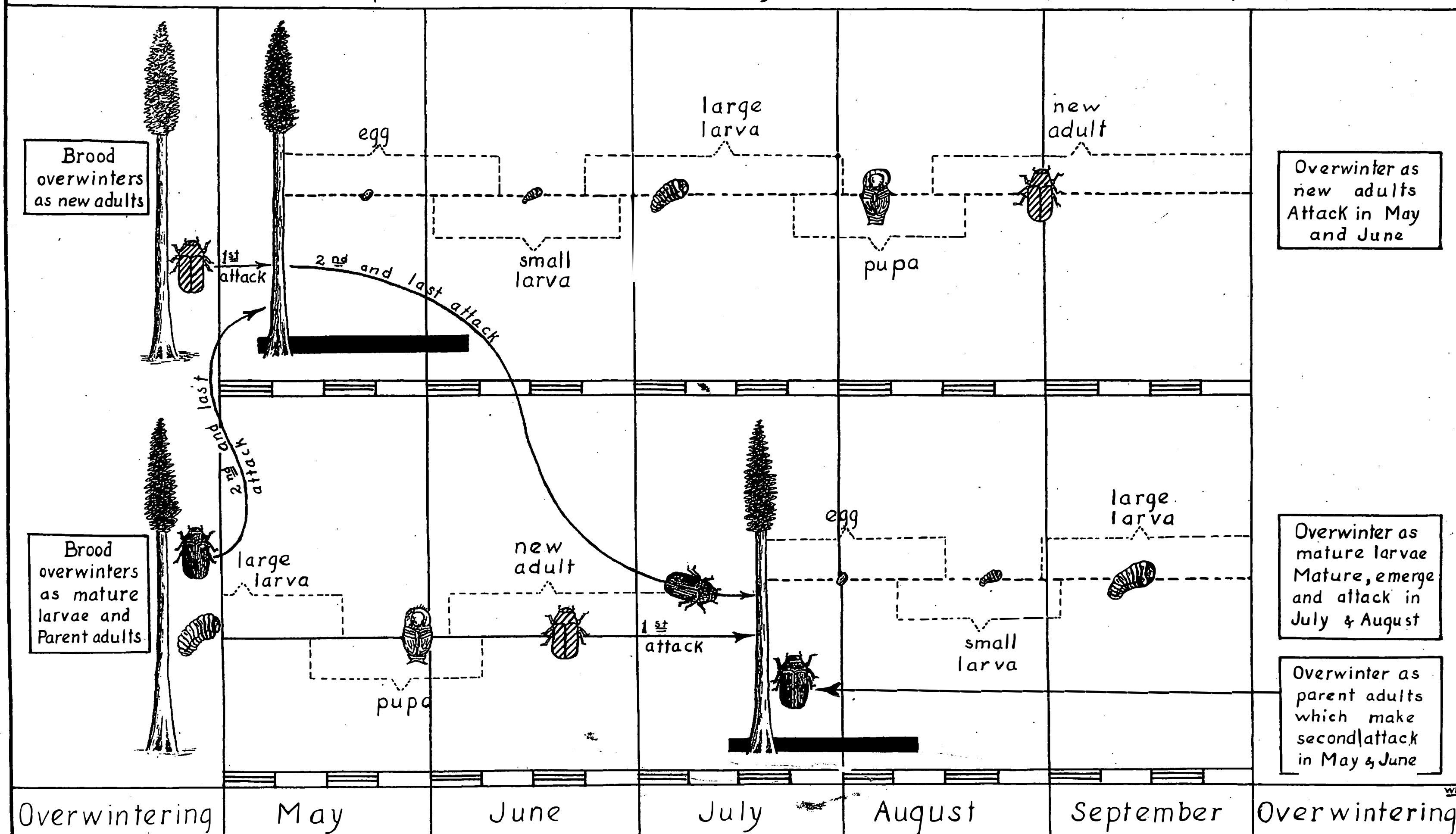
Black beetles - Parent adults, which are beetles that have already made one attack.

Cross-hatched beetles - New adults, which are beetles that have not yet made their initial attack.

Black lines - Extending from tree bases, represent the duration of the attack periods.

SEASONAL HISTORY OF DENDROCTONUS PSEUDOTSUGAE HOPK.

Showing attack periods – beetles causing attacks – and brood development



of trees, i.e., those containing mature larvae and parent adults; also, the new adults which attacked in May are now emerging to attack again and propagate their second and last brood. The parent adults which assisted in making the May attacks do not emerge again because they perpetrated their second and last attacks by entering the May trees. The broods propagated during the second attack period develop normally (Plate IV) and have reached the mature larval stage by the close of the season. The winter is passed in this stage, development is resumed in the spring, and the new adults emerge and attack during late July and early August. These are the trees which contain mature larvae and over-wintering parent adults in the spring of the year.

Regarding this seasonal history, two things must be remembered. First, that no tree contains a "pure line", that is, no tree contains brood propagated entirely by new adults, or entirely by parent adults making their second attacks. Instead, inasmuch as parent adults are attacking simultaneously with new adults during both attack periods, they attack trees together and may be found in varying percentages in the different trees. Secondly, it must be remembered that although the sequence of events will remain the same, climate will exert a very pronounced influence on brood development and thus may change the dates of the events if the yearly climatic variations are sufficiently pronounced.

End quo

BROOD POTENTIAL vs. STATUS OF INFESTATION

A few entomologists have been of the opinion for several years that brood potential should be a sound criterion of the status of the infestation. Were this true, investigators could predict, to a limited

extent, the rise or fall of any infestation by the simple expedient of examining representative bark samples. Such an easy method would be of immeasurable value in deciding whether or not control work should be done on any particular area, for, in the examination of the bark samples, the investigator could discern whether the infestation was increasing or decreasing.

Some experimentation regarding this subject has been performed, but unfortunately, the work was discontinued before final results were secured. It was decided, therefore, to attempt a correlation of this nature by making a 100 per cent survey every year for infested trees within a permanent plot comprising 320 acres. The brood potential was to be determined by examining two trees in each quarter section surrounding the surveyed area. The trees for examination were to be felled, and an examination made of quarter square-foot samples on all four sides of the tree at ten foot intervals, beginning at a height of 5 feet from the base of the tree. In addition to the counts of bark-beetle brood, counts were also made of parasites and predators in order to take cognizance of these in the construction of a formula whereby the rise and fall of infestations can be predicted by one year's examination. In the 1932 studies, infested trees could be located only north and south of the permanent plot so that in brood examinations six trees were examined north of the plot, and six trees on the south side.

The study was begun in September, 1932, so that data are available for one year only. The survey showed 461 trees infested during 1932 on the 320 acre plot, or an infestation of 1.44 trees per acre. The epidemic

therefore, at the time of the survey was quite severe. The brood examinations for the 1932 season are summarized in Table VII.

TABLE VII
SUMMARY OF BROOD COUNTS
MADE IN THE STUDY OF BROOD POTENTIAL

(INCL. NEW ADULTS)

Sq. ft. of bark examined	Total number of Attacks	Total number of Larvae	Total number of Pupae	Total number of New adults	No. of attacks per sq. ft.	No. of immature bark beetles per sq. ft.
76	651	103	10	925	8.5	13.6

It can be seen from the above table that even when parent adult emergence is considered, the beetles emerging from one square foot of bark would not be quite sufficient to infest two square feet. In addition, if mortality to the beetles during flight and attack is considered, it can readily be seen that the brood potential is barely sufficient to maintain the infestation at its present level. This is slightly lower than the brood potential secured from the 1931 investigations. Although no survey was conducted during that year, it is interesting to note the high percentage of mortality which occurred during the various stages of the insect's development. These examinations were made at different times in order to secure counts of the divers brood stages. For example, bark examinations were made early in the season to ascertain the number of eggs per square foot; later, counts were made when larvae were present in the trees, and so on for each developmental stage. In this way, the decrease in numbers from one stage to the next is secured and thus the mortality for each stage can be calculated. The results of these examinations are shown in Table VIII.

TABLE VIII
MORTALITY TO DOUGLAS-FIR BEETLE BROODS

Brood stage	Sq.ft. of bark examined	No. per square foot	Mortality in numbers	Per cent mortality	Per cent of total mortality
Egg	203	168 diff.	105 105/168 =	62.5	62.5 Causes
Larva	141	63	31	49.2	18.5
Pupa	94	32	7	21.8	4.1
New adult	149	25	7	28.0	4.1
No. emerged	164	18	Total mortality		89.2

Table VIII shows that there is a very high mortality due to natural causes to the Douglas-fir beetle broods in the infestation studied. Both Tables VII and VIII point to the fact that only sufficient beetles are surviving to maintain the infestation at its present level, inasmuch as there are an average of 8.5 attacks per square foot and a ratio of 1.6 beetles per attack. Whether this is substantiated or discredited by a levelling-off or a decrease in the infestation can be shown only by the yearly survey.

SAMPLE PLOTS 1/10-ac

Five permanent sample plots were established during the 1931 season to study the ecological changes and successions which occur in a stand of Douglas fir that has been infested by the Douglas-fir beetle. These plots, which were one-tenth acre in size, were situated one on each of the four cardinal exposures and one in a flat creek bottom. The plots were marked by corner posts and located in relation to section corners. All trees on the plots were numbered with metal tags and the data for each tree were recorded on separate cards. Increment cores were taken

from four sides of each Douglas fir within the plots as well as from infested and uninfested trees adjacent to the plots. These cores were analyzed but the data are too meagre to be used as a basis for definite conclusions.

The plots were reexamined in 1932, and no new infestations were found on the permanent areas with the exception of one tree on plot 3. No important changes were recorded, except that the trees attacked in 1931 had lost practically all their needles and some had begun to lose large pieces of bark from the upper portion of the trunk. A sap rot was rapidly destroying the sapwood of these dead trees, and had penetrated perhaps one inch into that part of the tree.

This study will require a long period of time for completion, so that no definite conclusions can be drawn at this time.

CONTROL

The ultimate aim of the preceding biological studies is to furnish data from which successful control methods can be evolved. In the furtherance of this objective, two methods of artificial control were tested in conjunction with the biological studies.

The insects and other Arthropods active in the biological control of the Douglas-fir beetle also were studied. This investigation was undertaken so that an understanding of these agents might be had whereby control methods could be revised in order to assist, rather than hinder, these beneficial creatures.

Artificial Control

The first of the artificial control methods attempted to destroy the bark beetle broods by peeling infested trees and thus exposing the

immature stages of the beetle to the attack of various predators. In this experiment, six infested Douglas-fir trees were felled and peeled on September 16, 1931. Previous to peeling, examinations were made on all of the trees in order to obtain brood counts whereby the per cent of any resulting control could be calculated.

On May 2, 1932, 22 square feet of this bark that had lain on the ground all winter, were placed in the galvanized cans previously described in the discussion of the sex studies. The following table shows the results of this study:

TABLE IX
MORTALITY TO D. PSEUDOTSUGAE AND PARASITE BY PEELING

Insect	No.? 1931 Before peeling	1932 Peeled and exposed over winter	Per cent mortality
D. pseudotsugae	36 /sq ft?	5	86
C. brunneri	25	1	96

Although the peeling of trees infested with the Douglas-fir beetle does destroy approximately 86 per cent of the bark beetle broods, it produces a more drastic effect upon the most important beneficial insect found to attack this pest.

Caging experiments were also conducted on the area where the trees were peeled in order to observe the action of the beetles under field conditions. Two cages were constructed, one over a portion of the peeled bark and the other on an area where peeled bark had lain but had been removed. Each cage contained a green log. These cages were constructed to determine if the beetles would attack after emerging and also if

beetles had overwintered in the duff as well as the bark. No attacks appeared in the cage over the duff, but the log in the cage enclosing the bark was attacked. This indicates that beetles did not overwinter in the duff, but did successfully overwinter in the peeled bark.

The second of the artificial control methods attempted to destroy the broods of D. pseudotsugae by injecting the infested trees with liquids that are toxic to the insects. Five trees were used in this experiment and were injected on July 20, 1931, as follows: One tree with one-half pound of sodium arsenate to three quarts of water, one tree with one-half pound of sodium arsenate to two quarts of water and one quart of wood alcohol, one tree with one-quarter pound of sodium arsenate to two quarts of water and one quart of wood alcohol, one tree with one-half pound of sodium arsenate to four and one-half pints of water and one and one-half pints of wood alcohol, one tree with three quarts of wood alcohol.

The solutions were injected into the trees by cutting a saw kerf around the base of the tree to a depth of one-quarter of an inch and nailing a tin collar around the tree just below the kerf. This collar flared outward and upward from the point of attachment to the tree, so that several quarts of liquid could be held between the collar and the tree. Leakage from the collar was prevented by smearing a mixture of paraffin, lubricating grease, and linoleum cement on the tree at the point where the collar was fastened. The liquid was then poured into the collar, and was then absorbed and distributed by the conducting tissues of the tree. All trees at the time of medication showed comparatively recent attacks, indicated by the presence of living cambium and brood in the egg and young larval stages.

These medicated trees were examined in May, 1932. The tree injected with three quarts of alcohol was the only one which showed no apparent kill. However, no satisfactory mortality was obtained in the other trees due to the fact that a portion of the Douglas-fir beetle larvae feed in the outer bark rather than between the bark and wood. More detailed examination indicated that the presence of the poison increased the number of larvae that migrated from the cambium to the bark, showing, that even when applied to new attacks, the poisoning of these beetles by tree injection is not an efficient means of control.

Biological Control

It was shown in the 1931 report that there is a natural mortality of approximately 89 per cent in Douglas-fir beetle broods in their development from the egg to the adult stage. This is due almost entirely to enemies of the beetle which are associated with it beneath the bark. Much has yet to be done in the study of these creatures, but unfortunately, a more pressing need for study in other fields resulted in but little work being done on this subject during the 1932 season. However, the work as far as completed will be included in this report.

Mites (Arachnida - Acarida)

Two undetermined species of mites have been observed feeding on *D. pseudotsugae* eggs in the newly constructed egg galleries. These Arthropods have also been kept in the laboratory and fed on bark-beetle eggs. They are very numerous in the galleries, and I believe account for a large percentage of egg mortality.

Only the adult form has been observed. These are found associated with the adults of the Douglas-fir beetle inasmuch as the mites are transported from the old host to the newly attacked tree by clinging to the migrating beetle. Adult mites have been collected during May and June from beetles about to emerge from the trees of the previous year's attack, and also in the newly attacked trees.

__Thanasimus dubius__ Fab. (Coleoptera - Cleridae)

This insect is undoubtedly the most important predator associated with the Douglas-fir beetle. Both the larva and imago are predacious, the larva feeding upon the immature stages of the bark beetle beneath the bark, and the adult preying upon the adult bark beetles as they begin to attack the tree. Although no satisfactory method has been devised whereby the exact amount of brood destroyed by a predator can be measured, a conservative estimate would place this between 10 and 20 per cent for __T. dubius__.

Egg (Plate V fig. 1)

The eggs are sub-cylindrical in shape, elongate ovoid in outline, with a slightly curved longitudinal axis. They are white, opaque and without surface markings. The average length is 1.923 mm.; the average width .428 mm.; maximum length 2.079 mm.; minimum length 1.666 mm.; maximum width .485 mm.; minimum width .381 mm.

Larva (Plate V, figs. 2,5,6,7,8)

The larva of this insect is described by Boving and Champlain[5].

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[5] Boving, Adam G., and Champlain, A. B. 1921. Larvae of North American Beetles of the Family Cleridae. Proc. U.S. Nat. Mus. 57: 575-650.

For general field use, the larva can be distinguished from other Coleopterous forms found in the Douglas fir by the following characters: average length 12.8 mm., color white in the newly hatched larva, purplish when mature; ventral portions paler; sclerotized plates brown ocher. Body composed of head, 3 thoracic and 9 abdominal segments. Head bearing well developed mouth parts; setae long and delicate, arranged as shown in Plate V, figs. 6 and 7; mandibular setae 2; retinaculum at middle of inner margin. Dorsum of prothorax bearing a hemispherical sclerotized plate; mesothorax bearing two sclerotized plates on dorsum, each smaller than prothoracic dorsal plate; metathorax similar to meso- but dorsal plates somewhat smaller. Body clothed with long delicate hairs. Apical abdominal segment bearing a heavy basal sclerotized plate on disc caudad. This larva can be distinguished from the other clerids found in Douglas fir by the cylindrical, very slightly converging cerci found on the basal plate. These are two-thirds the length of the plate; apices turned inward and recurved. The ocelli arranged in an anterior row of 3 and a posterior row of 2, the rows converging dorsad, and the rounded unbroken line of the frons in lateral view of the epicranium, also aid in distinguishing this species from E. sphegeus.

Pupa (Plate V, fig. 3)

The pupa averages 9.18 mm. in length. Color white, shining. Surface glabrous except for a few short delicate hairs on the dorsal portion of the frons. Frons with a vertical fossulet in the center. Strong mandibles, maxillary and labial palpi present. Antennae bent downward along pleura. Apices of wings sub-equal, extending almost to the apex of the second abdominal segment; apices of fore tarsi extending to apex of

thorax; those of mid tarsi, to apex of first abdominal; those of hind tarsi, slightly beyond the apex of the third abdominal segment. Apical segment bearing a bifid process.

Imago (Plate V, fig. 4)

The adult is readily recognizable in the field by its coloration and ant-like appearance as it runs over the bark surface. The average length is 10 mm. The color is as follows: head, meso- and metathorax black; antennae, prothorax, legs, abdomen and bases of elytra red, the abdomen brighter red than the others; the elytra black except the reddish bases, a band of greyish-white prostrate hairs forming a line from the inner margin, cauded and laterad across the elytron so that when the two are together they form an inverted V cephalad of the middle, and an irregular patch of similar hairs on the apical fourth which leaves a small irregular spot of black laterad and near the apex of the elytron. Antennae clavate, 11-segmented. Prothorax sub-globose, covered with long delicate hairs. Bases of elytra coarsely punctate. Tarsi 4-jointed, the basal joint of hind tarsi being equal to or longer than the next two combined.

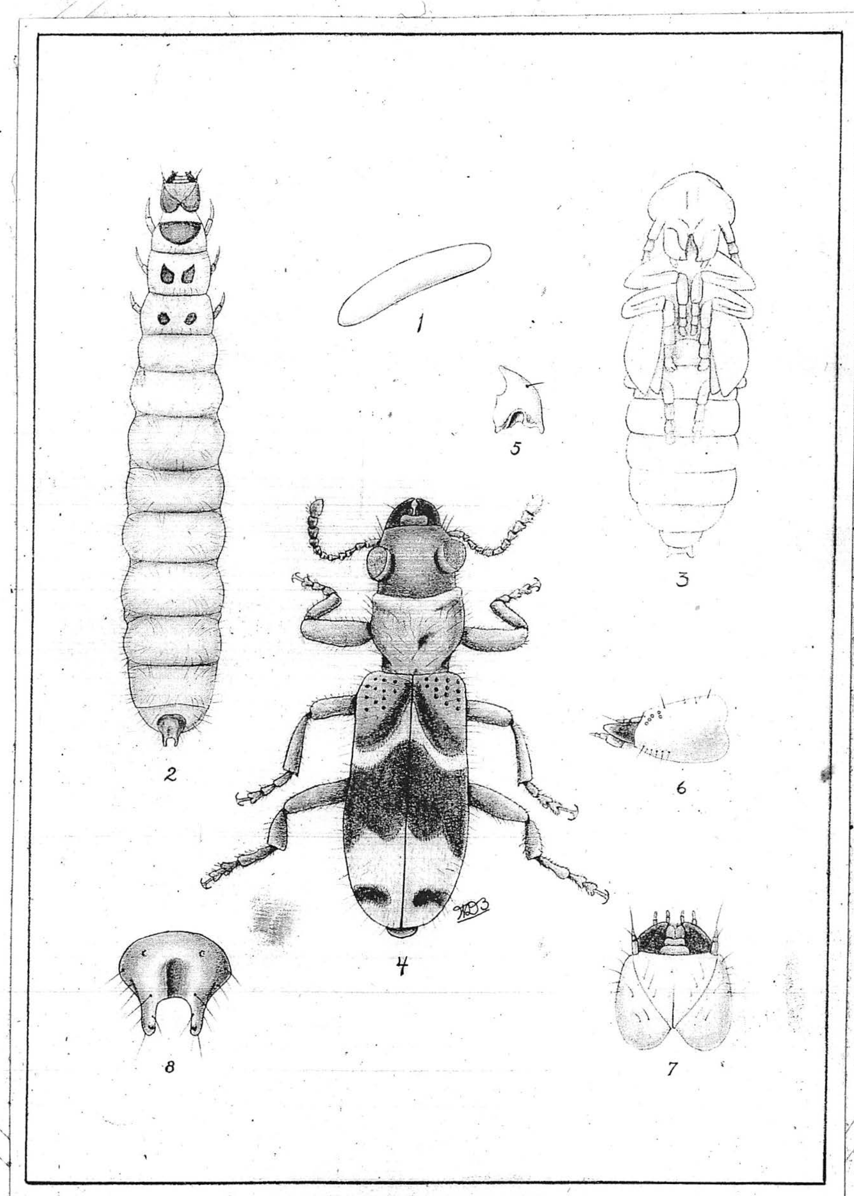
Seasonal History:

Adults begin to appear in late May and are abundant by the middle of June. Eggs are laid during June and young larvae are abundant by the second week in July. These feed throughout the remainder of the season, overwinter as larvae, pupate during May and emerge as adults during May and June of the following season. It appears that a few larvae pupate and emerge as adults during August and September of the same season in

PLATE V

<u>Thanasimus</u> <u>dubius</u> (Fab.)

1. Egg x 12.
2. Larva x 6. Dorsal view showing size and position of thoracic dorsal plates.
3. Pupa x 6. Ventral view.
4. Imago x 6. Dorsal view.
5. Right mandible of larva x 15. Dorsal view showing position of retinaculum.
6. Head of larva x 15. Lateral view of left side of epicranium showing arrangement of ocelli and smoothly rounded dorsal line.
7. Head of larva x 15. Dorsal view.
8. Basal plate x 15. Dorsal view showing size and shape of cerci.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which the eggs were laid. This, however, is uncommon.

Biology and Habits:

The adults can be found running rapidly over the bark surface of the newly attacked Douglas-fir trees. They are very rapid in their movements and when frightened, drop quickly to the ground. Mating takes place at this time and many pairs of beetles can be observed performing the copulatory act on the bark of the newly attacked trees. When searching for food, the beetles pause often and appear to be listening. Upon locating an adult Douglas-fir beetle, the Clerid grasps it firmly with its pro- and mesothoracic legs, braces itself with its hind legs, raises the anterior portion of the body slightly and begins to feed. The first incision is usually made in some portion of the venter, most commonly in the gular region. One adult kept in a rearing jar in the field laboratory and plentifully supplied with D. pseudotsugae adults, consumed 21 bark beetles and laid 49 eggs in a period of 30 days. This, of course, is no criterion as to the number of adults eaten under normal conditions, but it does indicate the capacity of one Clerid. When searching for a place in which to oviposit, the female stops often to test beneath bark scales and in bark crevices with her ovipositor. Eggs are laid in these places in groups of from 1 to 8, although groups of 2 or 3 are most common. The maximum number of eggs secured from any one female kept in rearing was 52.

The eggs require an average of 13 days for incubation. The maximum time requirement was 19 days and the minimum 11 days. Just before hatching, the larva wriggles about in the egg, bending it backward and forward until finally the chorion splits. The larva wriggles through this opening and proceeds to make its way to the cambium, taking advantage of attack

holes, ventilation holes and bark crevices. They feed on all the immature stages of the Douglas-fir beetle. An experiment performed with larvae kept in the field laboratory showed that the minimum number of bark-beetle larvae that could be eaten without starvation was one larva every 15 days. The maximum number that could be eaten was .85 per day. An average between these two figures shows that .44 larvae are eaten per day and this might be a good indication of the number eaten under normal conditions. The amount of food consumed seems directly responsible for the rapidity with which the larva matures and pupates. Those larvae fed the maximum number of bark-beetle larvae, matured and pupated at least 36 days before those fed the minimum number of larvae.

The larvae pupate either in the outer bark or in the ground. Those that pupate in the bark hollow out a small pupal chamber and line this with a silky material. The larva usually remains quiescent in a prepupal stage for about 10 days before pupation. The pupal stage requires an average of 20 days from the time of pupation to emergence of the adult.

Enoclerus sphegeus Fab. (Coleoptera - Cleridae)

This insect ranks quite closely to T. dubius in value as a control agent. However, its lesser numbers indicate that it does not destroy as much brood as does the former insect. Nevertheless, it is one of the most important predators attacking the Douglas-fir beetle. Both the larva and imago are predacious, the adult feeding upon the adult bark beetles, and the larva preying upon the immature stages beneath the bark.

Egg:

The egg is sub-cylindrical in shape, elongate ovoid in outline, with a slightly curved longitudinal axis. It is rose in color, shining

and without surface markings. The average length is 2.375 mm.; the average width, .597 mm.; the maximum length, 2.618 mm.; minimum length, 2.0 mm.; maximum width, .714 mm.; minimum width, .523 mm.

Larva:

The larva of this insect is described by Boving and Champlain (op.cit.). For distinguishing this larva from other Coleopterous species found in Douglas fir, the following characters can be used: average length, 20 mm.; color, rose in the newly hatched larva, purplish when mature; ventral portions, paler; sclerotized plates, brown ocher. Body composed of head, 3 thoracic and 9 abdominal segments. Head bearing well developed mouth parts and long delicate setae; retinaculum, large, closer to apex than to base of mandible. Dorsum of prothorax bearing a hemispherical sclerotized plate; mesothorax bearing two sclerotized plates on dorsum, each smaller than prothoracic dorsal plate; metathorax similar to meso- but dorsal plates somewhat smaller. Body clothed with long delicate hairs. Apical abdominal segment bearing a heavy basal sclerotized plate on disc caudad. This larva can be distinguished from the other Cleride found in Douglas fir by the cylindrical, sub-parallel cerci found on the basal plate. These are equal in length to the basal plate; directed slightly upward; apices turned inward and recurved. This larva is also distinguished by the conspicuous rounded protuberance on the epicranium dorsally and adjacent to the median part of the frontal suture, and by the arrangement of the ocelli which are in an anterior row of 3 and a posterior row of 2, the rows parallel.

Pupa:

Notes lacking.

Imago:

The adult of this insect can be recognized readily from other Clerids by its larger size, conspicuous markings, and distinctly hairy appearance. Average length, 12.0 mm. Color as follows: black with a bronzy cast except for carmine abdomen; frons with a large patch of dense, long white hairs; prothorax and legs sparsely covered with similar hairs; the elytra marked at the middle by a wide transverse band of small, dense, prostrate hairs; a patch of similar hairs varying in density appears on the apical quarter of the elytra. Antennae clavate, 11-segmented. Elytra covered with minute elevations. Tarsi 5-jointed.

Seasonal History:

Adults begin to appear in May and are abundant early in June. Eggs are laid at this time, and young larvae are abundant by the early part of July. These overwinter as mature larvae, pupate in May and emerge as adults in May and June of the following year.

Biology and Habits:

The actions of the adult of this insect on the bark of newly attacked trees are similar to those of E. dubius. Adults kept in rearing cages in the field laboratory, ate an average of .46 adult D. pseudotsugae per day. Eggs are deposited beneath bark scales and in bark crevices. The incubation period averages 16 days. The larvae upon hatching make their way to the cambium in a manner similar to the larvae of the preceding species, and begin to feed on the immature stages of the Douglas-fir beetle. Larvae kept in the laboratory ate an average of .51 bark-beetle larvae per day. Pupae have been observed in poorly

constructed pupal cells in the outer bark, and it is not known if in some instances pupation takes place in the ground. It is possible that the habits of this insect are similar to those of T. dubius. No observations were made on the length of the pupal stadium.

Enoclerus lecontei Wolc. (Coleoptera - Cleridae)

The scarcity of this insect in Douglas fir prohibits it from being of any great economic value in the control of the Douglas-fir beetle. Records kept of the insect population in bark samples showed that this insect comprised less than 1 per cent of the population in Douglas fir.

Egg:

Not observed.

Larva:

The larva averages 15 mm. in length. This species differs from the preceding one in having stouter cerci which are only one-third the length of the basal plate, parallel, apices recurved and not turned inward. The ocelli arranged as in the preceding species, but anterior and posterior rows converge dorsad. Epicranium lacking protuberance so that in lateral view the frons appears as a smooth slightly rounded line. Color, rose throughout life.

Pupa:

Not observed.

Imago:

The adult resembles T. dubius in size and general shape. Average length, 9.0 mm. Color, uniformly black; elytra marked with patches of

small, dense, greyish-white, prostrate hairs as follows: with elytra closed, a narrow transverse band forms an inverted V near the mid point; a wider transverse band appears near the base; a large patch on the apical quarter. Antennae clavate, 11-segmented. Fore and mid tarsi 5-jointed; hind tarsi 4-jointed, the basal joint as long as or longer than the next two combined.

Seasonal History, Biology and Habits:

But little has been learned regarding the activities of this insect in the locality in which the studies were made. Adults begin to appear about the middle of July and reach their maximum abundance by the first of August. The larvae probably winter over in an immature stage, continue feeding in the spring, pupate during July and emerge during July and August.

<u>Cucujus clavipes</u> Fab. var. <u>puniceus</u> Mann. (Coleoptera - Cucujidae)

This insect has a control value about equal to the preceding species. The larvae are predacious and although adults were plentiful, the eggs were not often deposited in Douglas fir and, consequently, this insect borders on rareness as an associate of the Douglas-fir beetle.

Egg:

The egg is sub-cylindrical in shape, elongate-ovoid in outline. Color, white; surface shining and unmarked. Average length, 2.18 mm.; average width, .44 mm.; maximum length, 2.23 mm.; minimum length, 2.13 mm.; maximum width .46 mm.; minimum width, .41 mm.

Larva:

Notes incomplete.

Pupa:

Notes incomplete.

Imago:

The adult is easily recognized by its flat body and red color. The antennae have the basal and apical joints red, the remainder piceous. The average length is 14 mm.

Seasonal History, Biology and Habits:

Because of its slight value as a control agent, but little study was made of this insect. The adults are abundant during May at which time they deposit their eggs beneath bark scales and in bark crevices. The winter is spent in the larval stage. The duration of the larval stage is not known, because larvae were found in July in trees from which the fir beetles had emerged in May.

Temnochila virescens Fab. var. chlorodea Mann. (Coleoptera - Ostomidae)

This insect is potentially a valuable agent in the control of the Douglas-fir beetle. However, its numbers in Douglas fir limit its value, and rank it close to E. lecontei in the amount of brood destroyed. The larva is an active predator which feeds on the immature stages of the Douglas-fir beetle.

Egg:

The eggs are white in color, subcylindrical in shape, and elongate-ovoid in outline. There are no surface markings. The average length is 2.30 mm.; the average width .46 mm.; maximum length 2.7 mm.; minimum length 2.1 mm.; maximum width .48 mm.; minimum width .43 mm.

Larva:

The larva resembles superficially those of the Cleridae already described. No larvae are at hand for description, but they can be distinguished from the Clerid larvae by the sclerotized plates on the dorsum of the thorax. The large plate is present on the dorsum of the prothorax as in the Cleridae, but instead of two small plates on the dorsum of the mesothorax as in the Clerids, there is but one plate somewhat smaller than the prothoracic one. The markings of the metathorax are similar to those of the Clerids.

Pupa:

Not observed.

Imago:

The adult is readily recognizable by its lustrous, bluish-green coloring. Average length 11 mm. Antennae capitate, the apical three segments wider and extended outward to form three serrations. Tarsi 4-jointed; apical joint as long as the basal 3 combined; pulvilli absent. Epicranium, pronotum, and elytra finely punctate; elytra irregularly striate.

Seasonal History, Biology and Habits:

Adults were observed in August ovipositing on a Douglas-fir tree attacked by _D. pseudotsugae_ in July of the same year. The eggs are laid beneath bark scales and in bark crevices, and the larvae undoubtedly make their way to the cambium in the same manner as the Clerids. Two adults were observed to feed on adults of the Douglas-fir beetle. The eggs require an average of 15 days for incubation. The larvae probably over-

winter, resume feeding in the spring, and pupate in the bark during late July and early August of the following year. The average length of the pupal period was found to be 13 days. However, this average was derived from records of only 4 pupae kept under laboratory conditions, so that the figure must not be taken as final.

MEDETERA ALDRICHII
~~Medeterus aldrichi~~ Wheeler (Diptera - Dolichopodidae)

The larvae of this fly are among the most important predators which feed on the immature forms of the Douglas-fir beetle. They are voracious feeders and unquestionably destroy much of the bark-beetle broods. However, a method has not been devised whereby the exact amount of brood destroyed by a predator can be measured and hence no statement can be made regarding the amount of control accomplished by this insect.

Egg (Plate VI fig. 1):

The eggs are elongate-oval in outline, slightly pointed at one end. The color is yellowish-orange, the pointed end bearing a darker, brownish cap. The entire surface is smooth and shining. The eggs average .857 mm. in length by .20 mm. in width. The maximum length .975 mm.; the minimum length .80 mm.; the maximum width .20 mm.; the minimum width .20 mm.

Hopping: 0.90 mm long, 0.21 mm wide (no mention of cap)

Larva (Plate VI figs. 2, 5):

The larvae upon hatching are but slightly longer than the egg, but upon reaching maturity, have an average length of 8.9 mm. They are creamy-white in color, slender, cylindrical, and taper anteriorly as well as posteriorly from the fifth and sixth abdominal segments, although the tapering is more pronounced cephalad.

The body is divided into a head, three thoracic and eight abdominal segments. The head is composed of two segments, the anterior one bearing the antennae and buccal appendages, the posterior one with an oval, brownish, sclerotized plate on the posterior half of the dorsum. A second, smaller, crescent-shaped, sclerotized plate appears on the dorsum of the prothorax near the anterior margin. The first to the seventh (inclusive) abdominal segments bear pseudopodia which are situated ventrad and cephalad and are furnished with rows of small locomotor spines. The apical segment has a circular band of these spinules in the center of the venter and a single row projects laterally on either side of the circular band.

DeLeon[6] in contradiction to Malloch[7] and Imms[8] states, "Malloch says that some larvae of the Dolichopodidae are peripneustic, and Imms states that the larvae of Medeterus have this type of respiratory system. However, all the larvae of Medeterus that were examined by the writer are amphipneustic --------". The findings of this writer agree with those of DeLeon in that the larvae of Medeterus aldrichi (Wheeler) have the amphipneustic type of respiratory system, the anterior pair of spiracles

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6 DeLeon, Donald 1931. The Important Parasites, Predators, and Associated Insects of the Mountain-Pine Beetle in Western White Pine. Unpublished report. 29.

7 Malloch, J. R. 1917. Preliminary Classification of the Diptera, Exclusive of Pupipara, based on Larval and Pupal Characters, with Keys to the Imagines in Certain Families. Bul. Ill. State Lab. 12:3:404.

8 Imms, A. D. 1925. A General Textbook of Entomology. Methuen & Co. Ltd. London. 638.

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being situated in the prothorax and the posterior pair in the apical abdominal segment.

Pupa (Plate VI fig. 3):

The pupa averages 4.4 mm. in length and is creamy-white in color. A pair of slender respiratory horns originate from the dorsum of the prothorax, cephalad, directly behind the eyes. A single transverse row of prostrate spines appears on the dorsum of all but the apical abdominal segment. A pair of spiracles or vestigial spiracles are found on all but the apical and penultimate abdominal segments. The apical segment bears a transverse row of long slender spines. The dorsum of the thorax has a few scattered short, stout spines. The wings extend to the apex of the second abdominal segment, the apices of the fore tarsi to the apex of the third, those of the mid tarsi to the apex of the fourth, and those of the hind tarsi to the apex of the fifth.

Imago (Plate VI fig. 4):

The adult averages 4.0 mm. in length and is black in color, with the exception that the front below the antennae is metallic blue, the basal joint of the antennae is straw-colored, and the dorsum of the thorax is vittate, bearing four whitish, longitudinal stripes. The scutellum bears two pairs of bristles. The pro- and mesothoracic tarsi have the first joint longer than the second; the metathoracic tarsi have the first joint never less than half the length of the second segment.

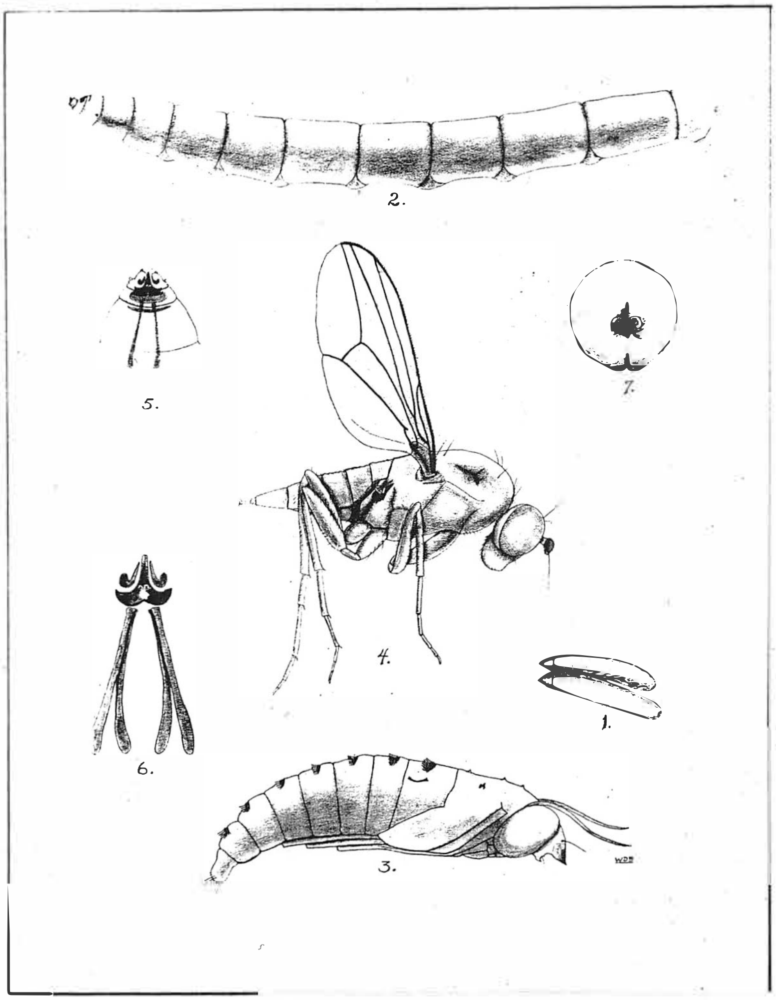
Seasonal History:

Adults begin to appear late in May and are abundant by early June. Egg laying in the newly attacked trees is begun almost immediately and

PLATE VI

Medetera aldrichi (Wheeler)

1. Eggs x 20.
2. Larva x 12. Lateral view.
3. Pupa x 12. Lateral view.
4. Image x 12. Lateral view.
5. Head of larva x 20. Dorsal view showing arrangement of buccal appendages and position of sclerotized plates on head and prothorax.
6. Buccal appendages of larva x 60. Dorsal view.
7. Apical segment of larva x 20. Caudal view showing position of posterior pair of spiracles.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young larvae of Medeterus are abundant by the first of July in the trees attacked by the Douglas-fir beetle during May. The larvae feed as long as larvae and pupae of the Douglas-fir beetle are available, which is about until the first of September. By this time the Medeterus larvae have reached maturity and pass the winter in this stage, either as pre-pupal larvae in pupal cells or as mature larvae. Pupation takes place during May and the adult flies emerge during the latter part of May and early June.

Eggs laid by females in the July attacks of the Douglas-fir beetle, produce larvae which winter over in a more immature stage than the larvae in the preceding group. They continue to feed in the spring, pupate in June and emerge as adults during June and July.

Biology and Habits:

The adults are found most abundantly on the newly attacked trees but may also be found in lesser numbers on unattacked trees and even trees of other species. They glide about over the bark and are capable of moving forward, backward or sideward with the same ease and gracefulness, although the forward motion is the most common. They feed upon small, soft-bodied Arthropods which they envelop by means of the labella while extracting the juices. Unfortunately, the identity of their prey was not determined. While gliding about over the bark, the female pauses now and again to feel beneath bark scales and in bark crevices with her ovipositor, probably searching for suitable spots on which to oviposit, as the eggs are found in such places. These are laid singly or in groups of two or three. Usually, two eggs are found.

The eggs hatch from 9 to 15 days, the average time being 11 days. Just before hatching, the young larva can be observed in the egg, with the last few abdominal segments bent so that the larva forms a J.

The young larvae wriggle through the bark to the cambium and begin to feed. They prey upon the eggs, larvae and pupae of the Douglas-fir beetle, the larvae of Coeloides brunneri (Vier.) and have been observed eating each other. They move about freely beneath the bark and apparently feed on whatever chances their way. When ready for pupation, the larva constructs a small cell composed of frass and minute pieces of cambium, the inside being lined with a silky substance. The larva appears in this cocoon, doubled back upon itself in the shape of a narrow U, in which shape it pupates.

The length of the pupal stadium is from 12 to 15 days, the average being 14 days.

Xylophagus abdominalis Lw. (Diptera - Xylophagidae)

The larvae of this insect were observed to feed on the larvae of the Douglas-fir beetle. However, as they were more often found feeding on and associated with Cerambycid larvae, it is assumed that their value is slight as an agent in the control of D. pseudotsugae. Although they undoubtedly reduce the bark-beetle broods by a small percentage.

Eggs:

Not observed.

Larva:

The mature larva ranges from 15 mm. to 20 mm. in length. The color is white, shining, except the sclerotized portions which are chest-

nut. The larva is composed of a head, three thoracic and eight abdominal segments. The head is not retractile, and is in the shape of a long, sharply pointed, sclerotized cone, with a small apical opening from which the mandibulate portions can be extended. First thoracic segment bears three rectangular sclerotized areas on the dorsum, separated by narrow, unsclerotized longitudinal lines. Second thoracic segment similarly marked. Third thoracic segment with conspicuous sclerotized areas on the dorsum. Dorsum of abdomen with a transverse band of locomotor spines on anterior margins of segments 1 to 6 inclusive. The venter also has transverse bands of locomotor spines on anterior margins of segments 1 to 7 inclusive. Apical abdominal segment very heavily sclerotized, ending in 2 divergent, slightly upwardly curved processes.

Pupa:

The pupa is slightly shining, testaceous, but becomes much darker as it approaches the time for transformation into the adult. The average length is 14 mm. Dorsum of head with 3 small punctiform depressions on ocellar region and with from 10 to 14 long hairs on each side of disc. Apices of wing extending beyond those of the fore tarsi; apices of mid and hind tarsi extending slightly beyond apices of wings. Apical segment of abdomen bearing a bifid process.

Image:

The adult is long and slender, averaging 14 mm. in length. The female is black, clothed with fine grayish hairs on thorax and abdomen; broadly ferruginous on disc of abdominal segments 2 and 3, the disc of segment 4 having the same coloring but restricted more to the cephalad portion; legs straw-colored, apical 2 joints of all tarsi blackened.

Squamae are vestigial. The costal vein is continued around the apex of the wing; the marginal vein ceasing before reaching the anal angle of the wing. Antennae three-jointed, the third joint appears to be divided into 8 distinct joints. Empodium pulvilliform, as large as the pulvilli, so that three rounded pads appear under the tarsal claws.

The male differs from the female in its slightly smaller size which averages 11 mm., in lacking the ferrugineous coloring on the abdomen, and in having the apex of the abdomen blunter and armed with a stout pair of sclerotized genital claspers.

Seasonal History, Biology and Habits:

Adults are found abundantly during June on trees attacked during May of the same season. Eggs are undoubtedly laid at this time, as small larvae are to be found in these trees during July. Mature larvae are present by September, and these winter over. Pupation takes place during the latter part of May, and the time required for the completion of this stage averages 8 days.

Lonchaea corticis Taylor (Diptera - Lonchaeidae)

Similar to Medeterus, the larvae of this fly are among the most important predators which feed on the immature forms of the Douglas-fir beetle. Again, owing to a lack of a suitable method whereby the exact amount of brood destroyed by a predator can be measured, no statement can be made regarding the amount of control accomplished by this insect. However, the larvae of L. corticis unquestionably destroy much of the D. pseudotsugae broods, possibly even more than Medeterus, as the larvae are more abundant in the infested trees than those of the latter species.

Egg (Plate VII fig. 2):

The eggs are elongate-oval in outline, slightly restricted at one end, the narrower end abruptly truncated. The color is pearly white, glabrous and shining. The eggs average .865 mm. in length by .175 mm. in width; the maximum length .885 mm.; the minimum length .80 mm.; the maximum width .20 mm.; the minimum width .15 mm.

Larva (Plate VII figs. 1, 6, 7):

The larvae upon hatching are but slightly longer than the egg, the mature larva, however, has an average length of 9.0 mm. Color creamy-white, slender, cylindrical, taper anteriorly from the apical abdominal segment.

The body consists of a head, three thoracic and eight abdominal segments. The head is retractile, bears small antennae and the buccal appendages. Pseudopodia, bearing locomotor spinules are situated caudad on the venter of each of the second to, and including, the eighth abdominal segments. The anterior spiracles are 9-lobed, situated laterad and caudad on the prothorax. The posterior pair is found on the apical abdominal segment, on the apex, dorsad, just below the disc. The posterior spiracles are heavily sclerotised, slightly raised, the sclerotization on the dorsal portion extending outward and upward to form a heavy, blunt, upcurved spine above the spiracle, the latter provided with three slits situated at right angles to each other. The apical abdominal segment shallowly punctate on the dorsal and caudal regions.

Pupa (Plate VII figs. 3,5):

The pupa is coarctate and is found within the indurated skin of the last instar larva which forms the reddish-brown puparium. The average length of the puparia is 5.2 mm.; that of the pupa 5.0 mm. The pupa is

creamy-white in color, slightly shining. The apices of wings extend to the apex of the third last abdominal segment; apices of fore tarsi to middle of same segment; apices of mid tarsi to apex of penultimate segment; those of hind tarsi to the middle of the apical segment.

Imago (Plate VII fig. 4):

The adult is a small, stout fly averaging 5.0 mm. in length. Thorax and abdomen green with a brilliant metallic luster. Head, coxae, femora and tibiae black; tarsi straw-colored except the 2 apical segments which are blackened. The front with a single row of bristles on either side; third antennal joint greatly elongated; tibiae of mid legs spurred. The body sparsely covered by stout, black bristles.

Seasonal History:

Adults begin to appear in late July and are abundant throughout August. Eggs are laid during August. These hatch and the young larvae feed throughout the remainder of the season, winter over in this stage and resume feeding in the spring of the following year. Pupation takes place during July and the adults emerge during July and August, one year after the eggs were laid.

Biology and Habits:

The adults can be found on the bark of infested trees attacked by the Douglas-fir beetle during the current season. The females crawl slowly over the bark but seem to use this method of locomotion only after having sighted while on the wing, a ventilation or parent adult emergence hole. The females hover close to the bark surface, moving slowly up, down, and around the tree, pausing frequently to hover over one particular spot. When an opening of any sort is located in the bark, the female settles on

PLATE VII

Lonchaea corticis (Taylor)

1. Larva x 10. Lateral view.

2. Egg x 12.

3. Pupa x 10. Lateral view.

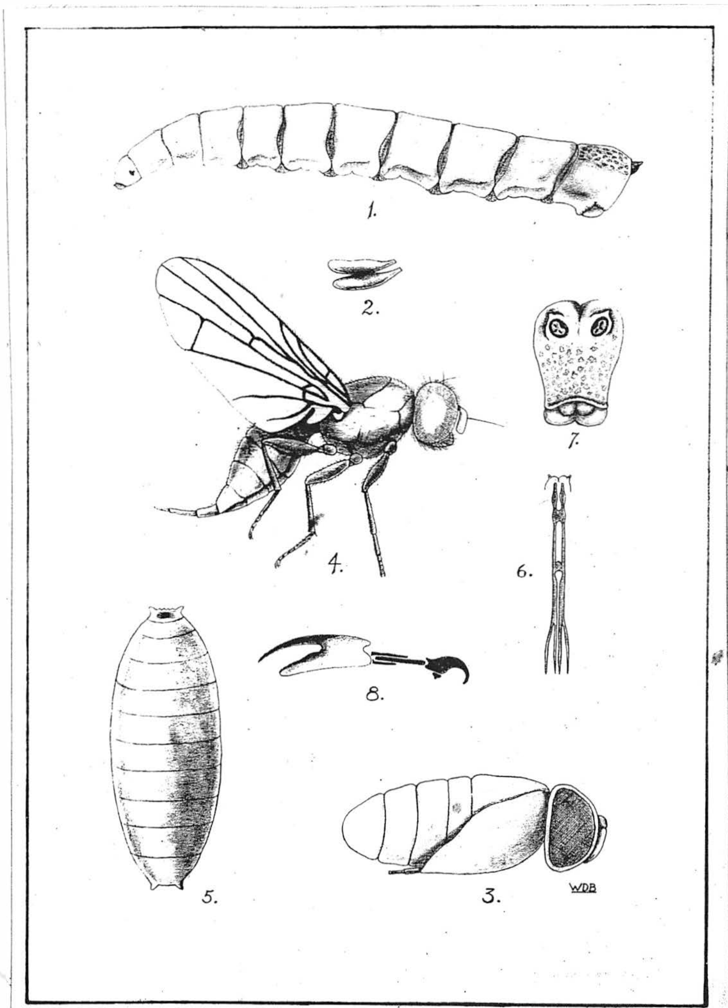
4. Imago x 10. Lateral view.

5. Puparium x 10.

6. Buccal appendages of larva x 20. Dorsal view.

7. Apical segment of larva x 12. Caudal view. Showing posterior pair of spiracles.

8. Buccal appendages of larva x 20. Lateral view.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the tree to inspect it more closely. She crawls around the hole and finally inserts her ovipositor as well as a portion of her abdomen. The eggs are usually laid in groups. An examination of 9 such groups showed an average of 30 eggs per group and these were laid in juxtaposition around the sides of the hole.

All the eggs observed, required exactly 6 days for incubation. Many larvae kept in rearing ate D. pseudotsugae eggs, larvae and pupae in varying numbers. The maximum number eaten was 3 larvae in 5 days, and one larva lived for 17 days without food. The larvae apparently find their food fortuitously, because bark-beetle larvae placed with Lonchaea larvae that had been without food for several days, were occasionally undiscovered for some time, but when discovery was finally made the predators would feed voraciously.

The pupal stadia lasted for surprisingly varied intervals. Puparia formed during July and kept under similar conditions produced adults in from 17 to 25 days. The average for 47 puparia was 22 days. Just before forming the puparium, the larva becomes very quiescent for one or two days.

Coeloides brunneri Vier. (Hymenoptera - Braconidae)

This insect was found to be the most important larval parasite of the Douglas-fir beetle, parasitizing an average of 29 per cent of the larvae. However, this percentage varies with the height on the tree, a greater number of Coeloides cocoons being found at the top of the tree than at the base. In the trees examined during the 1931 study, it was found that between 70 and 95 per cent of the beetle larvae had been parasitized in the upper ten feet of the infested tree length as compared with from zero to 10 per cent at the base. The cause of this variation has not as yet been determined.

Due to bark thickness — (ovipositor short)

In the 1932 investigations, 76 square feet of bark were examined from twelve trees and showed an average parasitism of 60.1 per cent. Consequently, if this insect can be aided rather than hindered by artificial control, a great improvement in our present control methods will have been made.

Egg (Plate VIII fig. 1):

The egg of this insect is pearly-white in color, glabrous and shiny; elongate-oval, nearly bottle-shaped in outline, with the smaller end usually curved. The average length is 1.73 mm., and the average width at the widest portion is .14 mm.

Larva (Plate VIII figs. 2, 3):

Upon hatching the larva is pearly-white, small and slender. When feeding is begun, however, it quickly fills out, becomes much plumper, and increases rapidly in size. The cuticula is very shiny and bears many short erect bristles. The head remains white throughout this stage and bears a brownish sclerotized design surrounding the buccal opening. The antennae are short, single-jointed and arise from large shallow depressions.

Pupa (Plate VIII figs. 4, 5):

The pupa also is white in color but grows darker as it matures. It usually pupates in a white silken cocoon, but rarely one may be found exposed. The pupa averages 5.3 mm. and the cocoon is but slightly larger.

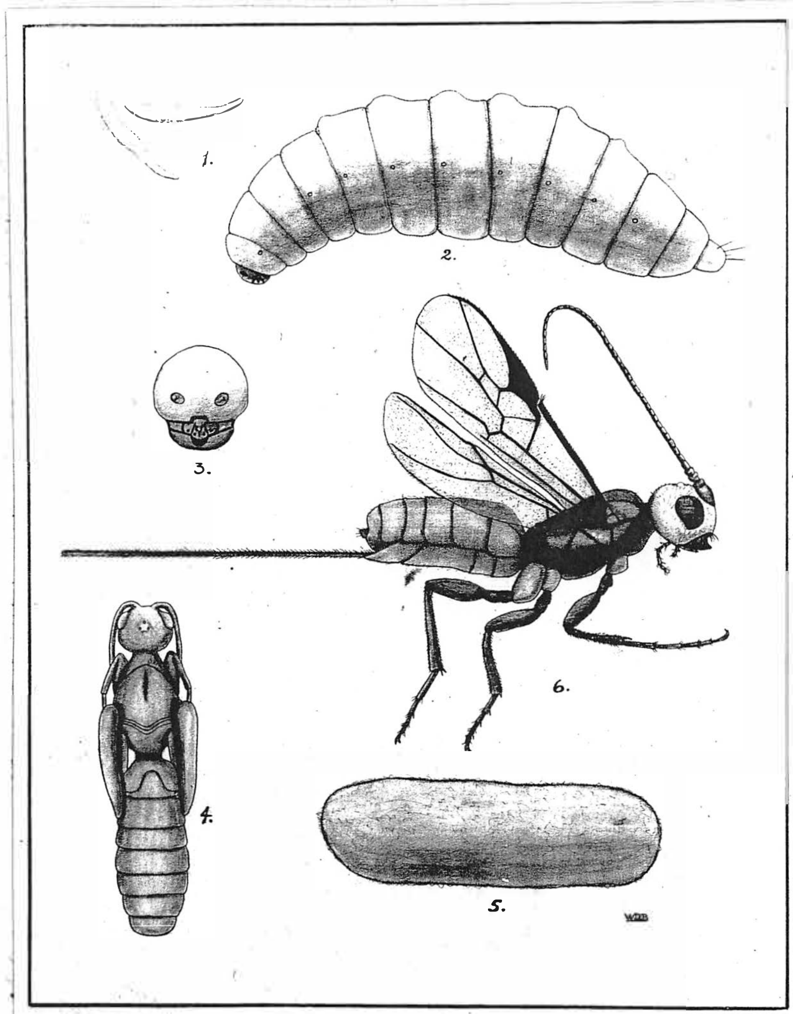
Imago (Plate VIII fig. 6):

The adult is small and wasp-like, the female possessing an ovipositor which averages 5.1 mm. in length. This, however, varies greatly

PLATE VIII

Cosloides brunneri (Vier.)

1. Eggs x 12.
2. Mature larva x 12. Lateral view.
3. Larval head capsule x 25.
4. Pupa x 10. Male, dorsal view.
5. Hibernaculum x 10.
6. Image x 10. Female, lateral view.



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with the size of the insects which themselves show a wide range. The length of the female averages 5.0 mm. exclusive of the ovipositor and the male 4.1 mm. The head, abdomen, coxae and trochanters of both sexes are red. The antennae, mandibles, compound eyes, thorax, femora, tibiae and tarsi of both sexes are black, as is the ovipositor of the female. The wings, more often than not, have a sooty coloring.

Seasonal History:

A very peculiar condition situation seems to be present in the seasonal history of this insect inasmuch as larvae, hatching from eggs deposited at the same time, will develop at extremely varied rates. This results in the presence of three distinct groups of C. brunneri, each possessing a different seasonal history.

In group I, the eggs are laid in July on the larvae of the Douglas-fir beetle which are in the May-attacked trees. The eggs hatch quickly, the resultant larvae develop rapidly, and by late August all of the parasite larvae have spun cocoons. In these they winter over as prepupal larvae, pupate in late June and emerge in July of the following year.

Group II arises simply through a more rapid development than group I. The eggs are oviposited at the same time on the D. pseudotsugae larvae in the same trees. Also, the eggs require approximately the same length of time to hatch and the larvae about the same time to develop. However, in place of remaining in the cocoons over the winter, these individuals pupate and emerge in August of the same year. They then mate and deposit eggs on the D. pseudotsugae larvae in the July attacks of that year. This group is very small, and only a small percentage of group I has this rapid development. The larvae hatching from the eggs laid in

August, may winter over in an unprotected state and spin cocoons in the spring, or may spin their cocoons in September of the same year and winter over in these. In either event they emerge as adults in August of the following year.

The eggs in group III are also laid in August in the trees attacked by the Douglas-fir beetle in July. The larvae hatching from these eggs may also winter over in a naked state and spin cocoons in the spring, or may spin cocoons in September of the same year and winter over in these. Observation of several trees shows that the latter practice is more common in this group as well as group II. Regardless of how the winter is spent, these larvae pupate and emerge as adults in August of the following year.

Biology and Habits:

The adults of this insect begin to appear in June, but do not become abundant until the middle of July. The males emerge first and remain on the bark of the tree from which they emerged, waiting for the females to appear. Emergence is accomplished by chewing their way directly from the cocoon, through the bark to the outside. When the females begin to appear, the males grow more and more excited, running up and down the tree, pausing now and again to flit their wings and "listen" with their antennae for an emerging female.

begin
pupate

When the drilling of an emerging female has been detected, several males crowd about the emergence point, pushing and jostling each other in an attempt to secure the most advantageous position. As she nears the surface, the males become more and more boisterous, until finally one of them will place himself over the exact point of emergence, flatten-

ing himself against the bark, and bracing his tarsi against the attempts of the others to dislodge him.

In consequence of this crowding and wrangling, every female is fertilized immediately upon her emergence and in some cases it has been noted that a female was fertilized by more than one male.

After fertilization, the female flies to a current attack of the Douglas-fir beetle and crawls about on the bark testing with her antennae to detect the movement of larvae beneath and to ascertain the suitability of these larvae as host material. Measurement of 200 head capsules of Douglas-fir beetle larvae found clinging to the Coeloides hibernacula, showed that only the fifth and a few fourth instar larvae were parasitized. Just how the female parasite determines the size of the larvae is not definitely known, but this probably is done by distinguishing between the volume of rasping produced by the larvae as they feed beneath the bark, assuming, of course, that the larger larvae produce a greater amount of noise as they tunnel about.

When the female has found a suitable larva, she raises her abdomen until the ovipositor is in a vertical position and finally places it directly over the larva, usually after considerable adjustment. She then moves her abdomen in various positions to force the ovipositor through the bark and when the host is reached, culminates the movement with a sudden violent down-thrust of the terebra. Then follows a short quiescent period during which the egg is probably deposited on the larva. Immediately after this, she withdraws her ovipositor, wipes it several times with her metathoracic legs and proceeds in search of another larva. The time required for this operation varies considerably, probably due to variations

in bark thickness, bark texture, and strength of the insects themselves. The 31 ovipositions observed, ranged in duration between 16 minutes and 84 minutes, but the majority lasted from 40 to 60 minutes.

The parasitized larva does not show the effect of parasitism immediately, but after several hours grows decidedly sluggish and at the end of one or two days it appears as if embalmed and makes no response to external stimuli.

All of the eggs kept in the laboratory hatched within 82 hours. The least time required for incubation was 27 hours.

The immature parasite, upon hatching selects a spot on the host suitable for feeding. Although possessing only vestigial mouthparts, the mandibles are well developed and it is with these that a hole is made in the host, through which the body juices can be obtained. From this point onward, growth is very rapid. Although many larvae were reared in plaster-of-paris pits in the laboratory, it was impossible to determine whether or not they pass through more than one instar. It is certain, however, that the head capsule never darkens and growth is so rapid that there seemed to be no time in which to molt. From the time of hatching to the time of spinning cocoons, these larvae require only from one to two weeks. This checks very closely with field conditions inasmuch as on August 1, cocoons were found to be abundant in trees in which Coeloides females were ovipositing during the middle of July.

The larvae pupate within their cocoons and spend approximately nine days in this stage before transforming to adults. Of those kept in the laboratory, the longest pupal stadium lasted 11 days, and the shortest six days.

Cecidostiba dendroctoni Ashm. (Hymenoptera - Pteromalidae)

This species was quite numerous in infested Douglas-fir trees and parasitizes the larvae of the Douglas-fir beetle. An undetermined Pteromalid which also was fairly abundant in the newly attacked trees, I believe to be another species in this genus. However, whether the *D. pseudotsugae* larvae are host for this species is not known. Consequently, only *C. dendroctoni* will be discussed in this report.

Egg:

Not observed.

Larva:

The mature larva has a maximum size of 6.1 mm., although the average is somewhat lower than this; color uniform greyish-white; head bearing scattered minute spines; body glabrous and shiny; mouth parts very simple and undeveloped.

Pupa:

The pupae vary greatly in length between 2.2 mm. and 6.0 mm., the male ranging considerably smaller than the female. The color is somewhat lighter than the larva, being a uniform pearly white. The color darkens, however, as the pupa matures.

Imago:

There is a considerable variation in the size of the adults. The males range between 2.2 mm., and 4.0 mm., and the females between 3.0 mm. and 6.0 mm. The main body coloring of the female is green: the head and thorax bright green with a metallic lustre; the abdomen darker but also with metallic lustre. The basal joint of the antennae, the

ocelli, the coxae, trochanters, tibiae and tarsi are straw-colored. The remainder of the antennae, the compound eyes, and the femora are piceous. The male differs from the female chiefly in that the two basal joints of the antennae are straw-colored, the abdomen bears a wide straw-colored band on the basal half, and the abdomen is short and round, whereas the female abdomen is long and pointed.

Seasonal History, Biology and Habits:

The adults begin to appear late in May and are abundant throughout the season. They can be found crawling about on the newly attacked trees. Although many females were observed to attempt oviposition through the bark in the thinner-barked portions of the trees, no eggs were ever collected from these spots. Many females were observed passing in and out of bark-beetle ventilation holes and parent adult emergence holes, which leads to the assumption that eggs are laid by females working directly in the egg galleries. However, this has not been definitely proven.

It is possible that this insect has two generations per year, but this is not known to be a fact.

The pupal stadium of twelve pupae which had been collected as larvae and reared in the laboratory, averaged 17 days. The shortest time required was 15 days and the longest 19 days.

<u>Pachyceras eccoptogasteri</u> Ratz. (Hymenoptera - Pteromalidae)

Similar to the above insect, this larval parasite was fairly abundant on the trees newly attacked by the Douglas-fir beetle. No exact figure was secured for the amount of parasitism by this species, but it

probably is approximately equal to or slightly less than the parasitism by the foregoing species.

Egg:

Not observed.

Larva:

The mature larva ranges between 3.3 mm. and 5.0 mm. in length. The color is uniform creamy white; body glabrous and shining.

Pupa:

The pupae vary in length from 1.7 mm. to 4.0 mm.; the males being considerably smaller than the females. The color is creamy white which darkens as the pupa approaches the time for transformation into the adult.

Imago:

The adults range between 1.7 mm. and 4.8 mm. in length. The head and thorax are dark green with a metallic lustre; the abdomen piceous with a small portion of the base metallic green; the antennae piceous with the basal joint lighter; coxae and trochanters metallic bluish-green; femora, brownish; tibiae and tarsi straw-colored.

Seasonal History, Biology and Habits:

The adults begin to appear late in May and are abundant by the second week in June. From this time on to the end of the season, they can be found on the newly attacked Douglas-fir trees. The females enter ventilation holes and open attack holes so that they may oviposit.

There are possibly two or more generations of this insect each year, but as yet the duration of the larval stage has not been determined. How-

ever, the winter is passed in this stage.

The larvae pupate wherever they might happen to be and make no especially constructed cell. Seven pupae reared in the laboratory required 12 to 18 days to pass from larvae to adults. The average was 16 days. The overwintering larvae pupate during early May.

Control Recommendations

Although considerable advancement has been made in our knowledge of agents active in the biological control of this bark beetle, there is such a tremendous amount of work yet to be accomplished that it is not feasible to recommend a direct application of this method of control at the present time. However, recommendations can be made for modifications in our present method whereby most of the important parasitic and predacious insects will be saved and thus control projects should be doubly efficient.

Mechanical means, therefore, must be relied upon at this time to control epidemics of the Douglas-fir beetle. Of the methods now in use, decking and burning has been found to be most efficient because of the thickness of Douglas-fir bark, the fact that approximately 40 per cent of the bark-beetle larvae tunnel in the bark and are, therefore, not exposed when the tree is peeled, and the fact that parent adult beetles emerge and make a second attack. The decking and burning method consists of felling the infested trees, cutting the infested length into logs, decking the logs, and burning the decks.

In the past, this method has always been applied in the fall of the year after all attacks for the current season had been made. However,

if control of the Douglas-fir beetle were undertaken during the month of June and only the attacks of the current season treated, there would be two advantages. First, it has been shown that the most valuable parasite (Coeloides brunneri Vier.) does not oviposit until July, so that by burning the new attacks during June, no C. brunneri would be destroyed. Secondly, the parent adults in the trees treated would be prevented from making their second attacks, resulting in a considerably smaller number of trees requiring treatment, and a greater volume of timber being saved.

In some cases, the country has been found to be so steep as to prohibit the use of ordinary logging methods. In these cases, hand logging has been accomplished successfully. It has been found that mere peeling produces only an 86 per cent mortality in the beetle broods, so that wherever possible peeling should be avoided.

In addition to the above precautions, the stumps should be cut low, and all infested stumps should be peeled.

ASSOCIATED INSECTS

Many other insects are associated with the Douglas-fir beetle, but only a list of the known forms will be given in this report because most of the biological data relating to them are incomplete at the present time. It is hoped that sufficient time will be available during the approaching field season to conduct further studies of these secondary insects and connect their immature stages with the proper image as well as establish the ecological position of each of these forms.

Begin quote

Order Collembola

Family Entomobryidae

Entomobrya sp.

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Order Corrodentia

Family Psocidae

Amphigerontia muculosus (Banks)

Order Hemiptera

Family Aradidae

Aradus proboscideus (Walker)

etc.

Aradus debilis (Uhler)

Order Coleoptera

Family Anisotominae

Agathidium revolvens Lec.

Family Staphylinidae

Tachyporus sp.

Phloeonomus sp.

Nudobius sp.

Quedius sp.

Family Buprestidae

Melanophila drummondi (Kirby)

Dicerca californica (Cr.)

{ Buprestis rusticorum Kby.
  Buprestis aurulenta L.

Family Nitidulidae

Epuraea truncatella (Mann.)

Family Rhizophagidae

Rhizophagus procerus (Csy.)

Family Melandryidae

Zilora nuda (Prov.)

Serropalpus barbatus (Schall.)

Family Cerambycidae

Spondylis sp.

Stenocorus lineatus (Oliv.)

Anoplerda canadensis (Oliv.)

Anoplerda aspera (Lec.)

Xylotrechus undulatus (Say.)

Leptura obliterata (Hald.)

Monochamus oregonensis (Lec.)

Acanthocinus obliquus (Lec.)

Tetropium velutinum (Lec.)

Family Scolytidae

Scolytus unispinosus (Lec.)

Scolytus ventralis (Lec.)

Scolytus monticolae (Sw.)

Crypturgus borealis (Sw.)

Polygraphus rufipennis (Kby.)

Pseudohylesinus nebulosus (Lec.)

Trypodendron ponderosae (Sw.)

Orthotomicus caelatus (Eichh.)

Dryocoetes pseudotsugae (Sw.)

Dryocoetes affaber (Mann.)

Order Lepidoptera

Family Oecophoridae

Epicallima coloradella (Wlsm.)

Order Diptera

Family Cecidomyiidae

Winnertzia sp.

Family Sciaridae

Sciara sp.

Family Ceratopogonidae

Forcipomyia sp. near pergandei var. concolor (Malloch)

Family Empididae

Tachypeza fenestrata (Say.)

Order Hymenoptera

Family Siricidae

Urocerus albicornis (Fabr.)

Family Braconidae

Helcon occidentalis (Cress.)

Macrocentrus aegeriae (Roh.)

Family Ichneumonidae

Rhyssa persuasoria (Linn.)

Rhyssa lineolata (Kby.)

Odontomerus tibialis (Cush.)

Xorides insularis (Cress.)

SUMMARY

The salient features of this report are as follows:

1. Parent adult Douglas-fir beetles emerge from the first tree which they attack, and attack a second tree. The parent beetles making their first attack in May, emerge and attack the second time in July.

Those making their first attack in July, overwinter and emerge to make their second attack in May of the following year.

2. In newly attacked trees, the attacking beetles have a sex ratio of 8 females to every 5 males. However, the new adults emerging from the old brood trees have a sex ratio of 1 male to 1 female. The inequality in new attacks is due to: first, the presence of a large number of parent beetles which emerge from their first attacks in a ratio of 5 females to 2 males; second, the greater mortality to males due to predators; third, the greater mortality to males due to their more hazardous existence.

3. Dendroctonus pseudotsugae Hopk. can not reproduce parthenogenetically.

4. The larvae of the Douglas-fir beetle pass through 5 larval instars, the duration of which is 6, 13, 16, 16, and 16 days respectively.

5. The Douglas-fir beetle has two attack periods, one in May, the other in July. The May attacks are made by overwintering new adults from the May attacks of the previous year, and overwintering parent adults from the July attacks of the previous year. The July attacks are made by new adults which overwintered as larvae, and the new adults which make their first attack in May later to emerge and make a second attack in July. The brood propagated by the May attacks overwinters in the new adult stage, emerges and attacks during May of the following year. The brood generated by the July attacks, overwinters in the larval stage, emerges and attacks during July of the following year.

6. An experiment has been instituted whereby the feasibility of correlating brood potential with the status of the infestation is being tested.

7. The peeling method of control reduces the Douglas-fir beetle broods only 86 per cent.

8. The injection of trees with solutions toxic to the bark beetles has not been found to be an efficient control measure in Douglas fir.

9. Certain parasitic and predacious Anthropods are found associated with the Douglas-fir beetle.

10. To control Douglas-fir beetle epidemics, the infested trees should be felled, bucked, decked and burned and wherever feasible this method should be applied during June.